## REMARKS

The art rejections are respectfully traversed.

Applicants' prior remarks are incorporated by reference and supplemented as follows.

Any of the Examiner's rejections and/or points of argument that are not addressed below or in the incorporated comments would appear to be moot in view of the following. Nevertheless, Applicants reserve the right to respond to those rejections and arguments and to advance additional arguments at a later date. No arguments are waived and none of the Examiner's statements are conceded.

Response to argument

Applicants again respectfully submit that US 6,185,277 (Harding) is not analogous to the present invention. The Examiner states that x-rays are a type of light. Applicants respectfully disagree. X-rays and light are both types of electromagnetic radiation, but x-rays are not an example of light. Attached is an article about electromagnetic radiation from www.wikipedia.org. This article includes a diagram showing the electromagnetic spectrum. This diagram shows the spectrum from highest energy on the left to lowest energy on the right. The categories are: gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwave, radio waves, and long radio

waves. Light and x-rays are clearly not the same. Those of ordinary skill in the art do not refer to the entire electromagnetic spectrum as "light" the way the Examiner does in the rejection & response to argument. Claim 11 is even clearer than claim 1 in this area because it refers to "visible" light.

Nor is generation of x-rays part of the same technology as generating light. Generating x-rays requires materials and levels of exciting energy that are entirely different from generating light. Also the tubes that contain the x-ray generation mechanism need to be of entirely different materials from the lamps used to generate light, because the high energy nature of x-rays makes those rays so dangerous and destructive. Often, even the emission windows need to be different materials, because different materials are absorbent or transparent to different energy levels of electromagnetic radiation. For these reasons, those who work in the field of designing x-ray tubes are skilled in a different art and not at all the same people who work in the field of designing lamps for generating light.

The Examiner has previously asserted that Harding's tube envelope is a discharge vessel filled with filling gas. Applicants have previously asserted that this tube vessel is evacuated, not filled with a filling gas – as explained in Harding's col. 3, lines 19-20. The reference clearly states that this is a vacuum space. Applicants find no support for the Examiner's assertion that there is a filling gas there. The Examiner has

not responded to this point of argument raised by Applicants in the previous amendment. Applicants respectfully submit that failure to consider this point is improper on the part of the Examiner.

Indeed Applicants do not understand how Harding's tube could work if there were a gas near the liquid metal target. The gas would absorb x-rays and might react with the liquid metal target, preventing it from functioning.

Applicants continue to assert that element 51 cannot be both a metal brazing layer and an organic adhesion layer (claims 4 and 5). This inconsistency is not related to the dependency of Applicant's claims. The Examiner has not indicated where in the reference her assertions about element 51 are supported. It is not clear that an organic adhesion layer could even function in an x-ray tube, in any case.

Applicants respectfully submit that the Examiner's assertions about the phrase "adapted to" continue to fail to reflect the law -- per MPEP section 2111.04, which does not strictly prohibit this phrase. Applicants respectfully submit that in the context of these claims the phrase does recite sufficient functionality as to be a basis for an argument of patentability. Applicants do not understand the word "positive" used by the Examiner in this context. The law does not prohibit the use of passive voice in claims.

The requirement for active voice could be construed as requiring that the tube

must actually be functioning in order for there to be infringement. It would follow that a tube that "can" perform a function, but is not turned on, might be interpreted as not infringing a claim. The law does not require that the language of the claim be restricted to tubes that are turned on as opposed to tubes that could be turned on. Applicants respectfully submit that the Examiner's assertions with respect to the phrase "adapted to" are therefore without basis in law.

Claim 12 recites that the vessel is adapted to produce light from at least one wall in response to radiation produced by the gas. The Examiner purports to find this in Harding. Applicants respectfully disagree. Harding clearly states at col. 3, lines 30-32 that the x-rays are produced by the electrons hitting the liquid metal target. This is a totally different mechanism from radiation produced by a gas within the discharge vessel striking the wall of the vessel. Applicants accordingly respectfully submit that the Examiner misconstrues the reference

With respect to Claim 13, Applicants vigorously contest the Examiner's assertion that an evacuated tube is a gas discharge lamp. A vacuum sealed container may contain a gas, but a "vacuum space" does not. Indeed even traces of a gas would likely prevent the x-ray tube from emitting x-rays.

Applicants further note that other arguments made in the prior communication were also not responded to. Applicant respectfully submits that these arguments be

considered and responded to, by the Examiner.

Reconsideration of the Office action, in view of the above, is accordingly respectfully submitted.

***Please charge any fees other than the issue fee to deposit account 14-1270. Please credit any overpayments to the same account.***

Applicants respectfully submit that they have addressed each issue raised by the Examiner – except for any that were skipped as moot – and that the application is accordingly in condition for allowance. Allowance is therefore respectfully requested.

Respectfully submitted,

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January 25, 2006

# Electromagnetic radiation

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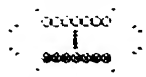
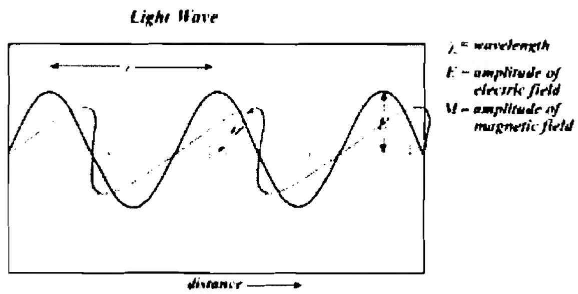


**Electromagnetism**
Electricity
Magnetism
**Electrostatics**
Electric charge
Coulomb's law
Electric field
Gauss's law
Electric potential
**Magnetostatics**
Ampere's law
Magnetic field
Magnetic moment
**Electrodynamics**
Electric current
Lorentz force law
Electromotive force
Electromagnetic induction
Faraday-Lenz law
Displacement current
Maxwell's equations
Electromagnetic field
**Electromagnetic radiation**
**Electrical circuits**
Electrical conduction
Electrical resistance
Capacitance
Inductance
Impedance
Resonant cavities
Waveguides
This box: view • talk • edit




Electromagnetic radiation can be imagined as a self-propagating transverse oscillating wave of electric and magnetic fields. This diagram shows a plane linearly polarised wave propagating from left to right.

**Electromagnetic radiation** is generally described as a self-propagating wave in space with electric and magnetic components. These components oscillate at right angles to each other and to the direction of propagation, and are in phase with each other. Electromagnetic radiation is classified into types according to the frequency of the wave: these types include, in order of increasing frequency, radio waves, microwaves, terahertz radiation, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays. In some technical contexts the entire range is referred to as just 'light'. [1]

EM radiation carries energy and momentum, which may be imparted when it interacts with matter.

**Electromagnetic waves** of much lower frequency than visible light were first predicted by Maxwell's equations and subsequently discovered by Heinrich Hertz. Maxwell derived a wave form of the electric and magnetic equations, revealing the wavelike nature of electric and magnetic fields and their symmetry.

According to these equations, a time-varying electric field generates a magnetic field and *vice versa*. Therefore, as an oscillating electric field generates an oscillating magnetic field, the magnetic field in turn generates an oscillating electric field, and so on. These oscillating fields together form an electromagnetic wave.

# Contents

### [edit] Properties

## [edit] Wave model

An important aspect of the nature of light is frequency. The frequency of a wave is its rate of oscillation and is measured in hertz, the SI unit of frequency, equal to one oscillation per second. Light usually has a spectrum of frequencies which sum together to form the resultant wave. Different frequencies undergo different angles of refraction.

A wave consists of successive troughs and crests, and the distance between two adjacent crests is called the wavelength. Waves of the electromagnetic spectrum vary in size, from very long radio waves the size of buildings to very short gamma rays smaller than atom nuclei. Frequency is inversely proportional to wavelength, according to the equation:

$$v = f\lambda$$

where $v$ is the speed of the wave ($c$ in a vacuum, or less in other media), $f$ is the frequency and $\lambda$ is the wavelength. As waves cross boundaries between different media, their speed changes but their frequency remains constant.

Interference is the superposition of two or more waves resulting in a new wave pattern. If the fields have components in the same direction, they constructively interfere, while opposite directions cause destructive interference.

The energy in electromagnetic waves is sometimes called radiant energy.

### [edit] Particle model

In the particle model of EM radiation, a wave consists of discrete packets of energy, or quanta, called photons. The frequency of the wave is proportional to the magnitude of the particle's energy. Moreover, because photons are emitted and absorbed by charged particles, they act as transporters of energy.

As a photon is absorbed by an atom, it excites an electron, elevating it to a higher energy level. If the energy is great enough, so that the electron jumps to a high enough energy level, it may escape the positive pull of the nucleus and be liberated from the atom in a process called photoionisation. Conversely, an electron that descends to a lower energy level in an atom emits a photon of light equal to the energy difference. Since the energy levels of electrons in atoms are discrete, each element emits and absorbs its own characteristic frequencies.

Together, these effects explain the absorption spectra of light. The dark bands in the spectrum are due to the atoms in the intervening medium absorbing different frequencies of the light. The composition of the medium through which the light travels determines the nature of the absorption spectrum. For instance, dark bands in the light emitted by a distant star are due to the atoms in the star's atmosphere. These bands correspond to the allowed energy levels in the atoms. A similar phenomenon occurs for emission. As the electrons descend to lower energy levels, a spectrum is emitted that represents the jumps between the energy levels of the electrons. This is manifested in the emission spectrum of nebulae. Today, scientists use this phenomenon to observe what elements a certain star is composed of. It is also used in the determination of the distance of a star, using the so-called red shift.

### [edit] Speed of propagation

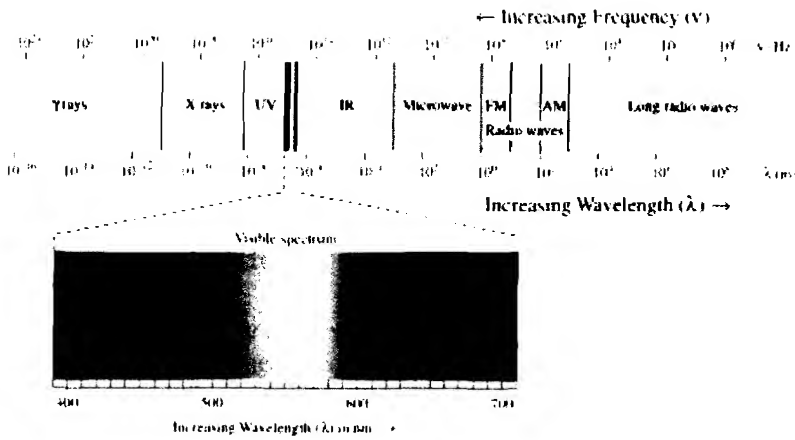
Any electric charge which accelerates, or any changing magnetic field, produces electromagnetic radiation. Electromagnetic information about the charge travels at the speed of light. Accurate treatment thus incorporates a concept known as retarded time (as opposed to advanced time, which is unphysical in light of causality), which adds to the expressions for the electrodynamic electric field and magnetic field. These extra terms are responsible for electromagnetic radiation. When any wire (or other conducting object such as an antenna) conducts alternating current, electromagnetic radiation is propagated at the same frequency as the electric current. Depending on the circumstances, it may behave as a wave or as particles. As a wave, it is characterized by a velocity (the speed of light), wavelength, and frequency. When considered as particles, they are known as photons, and each has an energy related to the frequency of the wave given by Planck's relation $E = h\nu$, where $E$ is the energy of the photon, $h = 6.626 \times 10^{-34}$ J·s is Planck's constant, and $\nu$ is the frequency of the wave.

One rule is always obeyed regardless of the circumstances: EM radiation in a vacuum always travels at the speed of light, *relative to the observer*, regardless of the observer's velocity. (This observation led to Albert Einstein's development of the theory of special relativity.)

In a medium (other than vacuum), velocity of propagation or refractive index are considered, depending on frequency and application. Both of these are ratios of the speed in a medium to speed in a vacuum.

## [edit] Electromagnetic spectrum

*Main article: electromagnetic spectrum*




Electromagnetic spectrum with light highlighted

| CLASS | FREQUENCY | WAVELENGTH | ENERGY |
|---|---|---|---|
| γ | 300 EHz | 1 pm | 1.24 MeV |
| | 30 EHz | 10 pm | 124 keV |
| | 3 EHz | 100 pm | 12.4 keV |
| SX | 300 PHz | 1 nm | 1.24 keV |
| | 30 PHz | 10 nm | 124 eV |
| | 3 PHz | 100 nm | 12.4 eV |
| NIR | 300 THz | 1 μm | 1.24 eV |
| MIR | 30 THz | 10 μm | 124 meV |
| FIR | 3 THz | 100 μm | 12.4 meV |
| EHF | 300 GHz | 1 mm | 1.24 meV |
| SHF | 30 GHz | 1 cm | 124 μeV |
| UHF | 3 GHz | 1 dm | 12.4 μeV |
| VHF | 300 MHz | 1 m | 1.24 μeV |
| HF | 30 MHz | 1 dam | 124 neV |
| MF | 3 MHz | 1 hm | 12.4 neV |
| LF | 300 kHz | 1 km | 1.24 neV |
| | 30 kHz | 10 km | 124 peV |
| VF | 3 kHz | 100 km | 12.4 peV |
| | 300 Hz | 1 Mm | 1.24 peV |
| | 30 Hz | 10 Mm | 124 feV |

**Legend:**

γ = Gamma rays
HX = Hard X-rays
SX = Soft X-Rays
EUV = Extreme ultraviolet
NUV = Near ultraviolet
Visible light

NIR = Near infrared
MIR = Moderate infrared
FIR = Far infrared

**Radio waves:**
EHF = Extremely high frequency (Microwaves)
SHF = Super high frequency (Microwaves)
UHF = Ultrahigh frequency
VHF = Very high frequency
HF = High frequency
MF = Medium frequency
LF = Low frequency
VLF = Very low frequency
VF = Voice frequency
ELF = Extremely low frequency

Generally, EM radiation is classified by wavelength into electrical energy, radio, microwave, infrared, the visible region we perceive as light, ultraviolet, X-rays and gamma rays.

The behavior of EM radiation depends on its wavelength. Higher frequencies have shorter wavelengths, and lower frequencies have longer wavelengths. When EM radiation interacts with single atoms and molecules, its behavior depends on the amount of energy per quantum it carries.

Spectroscopy can detect a much wider region of the EM spectrum than the visible range of 400 nm to 700 nm. A common laboratory spectroscope can detect wavelengths from 2 nm to 2500 nm. Detailed information about the physical properties of objects, gases, or even stars can be obtained from this type of device. It is widely used in astrophysics. For example, many hydrogen atoms emit radio waves which have a wavelength of 21.12 cm.

## [edit] Light

*Main article: light*

EM radiation with a wavelength between approximately 400 nm and 750 nm is detected by the human eye and perceived as visible light.

If radiation having a frequency in the visible region of the EM spectrum reflects off of an object, say, a bowl of fruit, and then strikes our eyes, this results in our visual perception of the scene. Our brain's visual system processes the multitude of reflected frequencies into different shades and hues, and through this not-entirely-understood psychophysical phenomenon, most people perceive a bowl of fruit.

In the vast majority of cases, however, the information carried by light is not directly detected by human senses. Natural sources produce EM radiation across the spectrum,

and our technology can also manipulate a broad range of wavelengths. Optical fiber transmits light which, although not suitable for direct viewing, can carry data that can be translated into sound or an image. The coding used in such data is similar to that used with radio waves.

### [edit] Radio waves

*Main article: radio frequency*

Radio waves carry information by varying a combination of the amplitude, frequency and phase of the wave within a frequency band.

When EM radiation impinges upon a conductor, it couples to the conductor, travels along it, and induces an electric current on the surface of that conductor by exciting the electrons of the conducting material. This effect (the skin effect) is used in antennas. EM radiation may also cause certain molecules to absorb energy and thus to heat up; this is exploited in microwave ovens.

## [edit] Derivation

Electromagnetic waves as a general phenomenon were predicted by the classical laws of electricity and magnetism, known as Maxwell's equations. If you inspect Maxwell's equations without sources (charges or currents) then you will find that, along with the possibility of nothing happening, the theory will also admit nontrivial solutions of changing electric and magnetic fields. beginning with Maxwell's equations for a vacuum:

$$\nabla \cdot \mathbf{E} = 0 \qquad (1)$$

$$\nabla \times \mathbf{E} = -\frac{\partial}{\partial t}\mathbf{B} \qquad (2)$$

$$\nabla \cdot \mathbf{B} = 0 \qquad (3)$$

$$\nabla \times \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial}{\partial t}\mathbf{E} \qquad (4)$$

where
$\nabla$ is a vector differential operator (see Del)

One solution is trivial,

$$\mathbf{E} = \mathbf{B} = 0$$

But there is a more interesting one. To see it one can use a useful vector identity which works for any vector:

$$\nabla \times (\nabla \times \mathbf{A}) = \nabla (\nabla \cdot \mathbf{A}) - \nabla^2 \mathbf{A}$$

To see how we can use this take the curl of equation (2):

$$\nabla \times (\nabla \times \mathbf{E}) = \nabla \times \left( -\frac{\partial \mathbf{B}}{\partial t} \right) \tag{5}$$

Evaluating the left hand side:

$$\nabla \times (\nabla \times \mathbf{E}) = \nabla (\nabla \cdot \mathbf{E}) - \nabla^2 \mathbf{E} = -\nabla^2 \mathbf{E} \tag{6}$$

where we simplified the above by using equation (1).

Evaluate the right hand side:

$$\nabla \times \left( -\frac{\partial \mathbf{B}}{\partial t} \right) = -\frac{\partial}{\partial t} (\nabla \times \mathbf{B}) = -\mu_0 \epsilon_0 \frac{\partial^2}{\partial^2 t} \mathbf{E} \tag{7}$$

Equations (6) and (7) are equal, so this results in a <u>differential equation</u> for the electric field:

$$\nabla^2 \mathbf{E} = \mu_0 \epsilon_0 \frac{\partial^2}{\partial t^2} \mathbf{E}$$

Applying a similar pattern results in similar differential equation for the magnetic field

$$\nabla^2 \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial^2}{\partial t^2} \mathbf{B}$$

These differential equations are equivalent to the <u>wave equation</u>:

$$\nabla^2 f = \frac{1}{v^2} \frac{\partial^2 f}{\partial t^2}$$

where
$v$ is the velocity of the wave and
$f$ describes a displacement

So notice that in the case of the electric and magnetic fields, the velocity is:

$$v = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Which, as it turns out, is the speed of light. Maxwell's equations have unified the permittivity of free space $\varepsilon_0$, the permeability of free space $\mu_0$, and the speed of light itself, c. Before this derivation it was not known that there was such a strong relationship between light and electricity and magnetism.

But these are only two equations and we started with four, so there is still more information pertaining to these waves hidden within Maxwell's equations. Let's consider a generic vector wave for the electric field.

$$\mathbf{E} = \mathbf{E}_0 f\left(\hat{\mathbf{k}} \cdot \mathbf{x} - ct\right)$$

Here $\mathbf{E}_0$ is the constant amplitude, $f$ is any second differentiable function, $\hat{\mathbf{k}}$ is a unit vector in the direction of propagation, and $\mathbf{x}$ is a position vector. We observe that $f\left(\hat{\mathbf{k}} \cdot \mathbf{x} - ct\right)$ is a generic solution to the wave equation. In other words

$$\nabla^2 f\left(\hat{\mathbf{k}} \cdot \mathbf{x} - ct\right) = \frac{1}{c^2} \frac{\partial^2}{\partial^2 t} f\left(\hat{\mathbf{k}} \cdot \mathbf{x} - ct\right),$$

for a generic wave traveling in the $\hat{\mathbf{k}}$ direction. The proof of this is trivial.

This form will satisfy the wave equation, but will it satisfy all of Maxwell's equations, and with what corresponding magnetic field?

$$\nabla \cdot \mathbf{E} = \hat{\mathbf{k}} \cdot \mathbf{E}_0 f'\left(\hat{\mathbf{k}} \cdot \mathbf{x} - ct\right) = 0$$
$$\mathbf{E} \cdot \hat{\mathbf{k}} = 0$$

The first of Maxwell's equations implies that electric field is orthogonal to the direction the wave propagates.

$$\nabla \times \mathbf{E} = \hat{\mathbf{k}} \times \mathbf{E}_0 f'\left(\hat{\mathbf{k}} \cdot \mathbf{x} - ct\right) = -\frac{\partial}{\partial t}\mathbf{B}$$
$$\mathbf{B} = \frac{1}{c}\hat{\mathbf{k}} \times \mathbf{E}$$

The second of Maxwell's equations yields the magnetic field. The remaining equations will be satisfied by this choice of $\mathbf{E}, \mathbf{B}$.

Not only are the electric and magnetic field waves traveling at the speed of light, but they have a special restricted orientation and proportional magnitudes, $E_0 = cB_0$. The electric

field, magnetic field, and direction of wave propagation are all orthogonal and the wave propagates in the same direction as $\mathbf{E} \times \mathbf{B}$.

From the viewpoint of an electromagnetic wave traveling forward, the electric field might be oscillating up and down, while the magnetic field oscillates right and left; but this picture can be rotated with the electric field oscillating right and left and the magnetic field oscillating down and up. This is a different solution that is traveling in the same direction. This arbitrariness in the orientation with respect to propagation direction is known as polarization.

## [edit] See also

- Control of electromagnetic radiation
- Electromagnetic pulse
- Electromagnetic spectrum
- Electromagnetic radiation hazards
- Electromagnetic wave equation
- Finite-difference time-domain method
- Helicon
- Klystron
- Light
- Maxwell's equations
- Photon polarization
- Radiant energy
- Sinusoidal plane-wave solutions of the electromagnetic wave equation
- Radiation reaction
- Pana-Wave Laboratory - a religious cult that believes in scalar electromagnetic waves

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1. ^ National Synchrotron Light Source, U.S.A., which refers to the entire EM spectrum as 'light'

## [edit] External links

- Electromagnetism - a chapter from an online textbook
- *Electromagnetic Waves from Maxwell's Equations* on Project PHYSNET.
- Ecolibria:More information and testing for EMR in Australia
- Conversion of frequency to wavelength and back - electromagnetic, radio and sound waves
- eBooks on Electromagnetic radiation and RF
- The Science of Spectroscopy - supported by NASA. Spectroscopy education wiki and films - introduction to light, its uses in NASA, space science, astronomy, medicine & health, environmental research, and consumer products.

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